Immediate and Long-term Results of Bronchial Artery Embolization for Life-Threatening Hemoptysis*

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Study objectives: Bronchial artery embolization (BAE) has been established as an effective technique in the emergency treatment of life-threatening hemoptysis, but few data concerning long-term results and complications of the procedure are available. The aim of this study was to analyze retrospectively the experience of BAE in our center with particular emphasis on medium-term and long-term results and on morbidity.

Setting: University hospital.

Patients: Fifty-six patients underwent bronchial arteriography from 1986 to 1996 in our center for the management of life-threatening hemoptysis. Of them, BAE was performed in 46 patients. Their mean age was 51 years (range, 19 to 89 years). The most frequent etiologies of hemoptysis were active or inactive tuberculosis, bronchiectasis, or idiopathic hemoptysis.

Results: BAE resulted in an immediate cessation of hemoptysis in 43 of the initial 56 patients (77%). During the first month after BAE, four patients who died from causes other than hemoptysis or who were referred to surgery were excluded from follow-up and in the 39 remaining patients, a complete cessation of hemoptysis was observed in 32 patients. A remission was noted in 28 of the 29 patients followed up between 30 and 90 days after BAE. Long-term control of bleeding was achieved in 25 of the initial 56 patients (45%) followed up beyond 3 months after BAE (median follow-up of 13 months; range, 3 to 76 months). Overall, complications of BAE consisted of two episodes of mediastinal hematoma and three episodes of neurologic damage, two of which improved without permanent sequelae.

Conclusion: We conclude that BAE may result in long-term as well as immediate control of life-threatening hemoptysis but that complications are not unusual.

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Key words: bronchial arteries; embolization; therapeutic; hemoptysis

Abbreviations: BAE = bronchial artery embolization

In life-threatening hemoptysis, bleeding originates in most cases from bronchial arteries or from nonbronchial systemic collateral vessels. Bronchial artery embolization (BAE), first introduced two decades ago by Remy and associates, was thus a logical therapeutic approach. Embolization was rapidly established and popularized as an effective means to achieve immediate control of active hemoptysis. Remote in time from the procedure, a high rate of recurrent hemoptysis due to revascularization is expected, but few data concerning long-term results are available. Even if they are infrequent, the potential complications of BAE cannot be neglected since they may be severe. In particular, the potential risk of spinal cord injury must be considered.

The aim of this study was to analyze retrospectively the experience of BAE in our center with particular emphasis on immediate and long-term results and on morbidity.

Materials and Methods

Patients

From December 1985 to May 1997, 56 patients underwent bronchial arteriography for life-threatening hemoptysis in our
Life-threatening hemoptysis was defined as expectoration of at least 200 mL of blood per hour in a patient with normal or nearly normal lung function, production of at least 50 mL of blood per hour in a patient with chronic respiratory failure, or more than two episodes of moderate hemoptysis (at least 30 mL) in a patient with a chronic respiratory failure, or nearly normal lung function, production of at least 200 mL of blood per hour in a patient with normal or nearly normal lung function.

Life-threatening hemoptysis was defined as expectoration of at least 200 mL of blood per hour in a patient with chronic respiratory failure, or nearly normal lung function, production of at least 200 mL of blood per hour in a patient with normal or nearly normal lung function.

Active bleeding, the delay between the procedure and cessation of hemoptysis was classified as idiopathic when the combination of CT scan of the chest, lung perfusion scan, fiberoptic bronchoscopy, and microbiological analysis of airway secretions disclosed no abnormalities. We did not perform pulmonary angiography in any patient because abnormalities of bronchial or nonbronchial arteries were found in all cases. All patients had been hospitalized in our ICU. Early chest radiography and flexible bronchoscopy were performed at the bedside at the time of ICU admission to lateralize the bleeding side, localize the specific site, and identify the cause of hemoptysis. All patients underwent standard medical management, including correction of hypoxemia with high concentrations of oxygen through a face mask, IV vasopressin,3,6 and antibiotics in case of documented or suspected bacterial infection. The patients with active tuberculosis were given antituberculous treatment. In 12 cases, BAE was performed while the patient was treated with mechanical ventilation.

**Technique of BAE**

In all cases, BAE was performed during active bleeding or soon after bleeding cessation. When BAE was not performed during active bleeding, the delay between the procedure and cessation of bleeding was never more than 6 h. This delay is ascribed to the fact that, in our center, the angiographers on duty are on call at the bedside at the time of ICU admission to lateralize the bleeding side, localize the specific site, and identify the cause of hemoptysis. All patients underwent standard medical management, including correction of hypoxemia with high concentrations of oxygen through a face mask, IV vasopressin,3,6 and antibiotics in case of documented or suspected bacterial infection. The patients with active tuberculosis were given antituberculous treatment. In 12 cases, BAE was performed while the patient was treated with mechanical ventilation.

**Table 1—Underlying Etiologies of Hemoptysis in the 46 Patients Who Underwent BAE**

<table>
<thead>
<tr>
<th>Etiologies</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuberculosis</td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>12</td>
</tr>
<tr>
<td>Sequelae</td>
<td>11</td>
</tr>
<tr>
<td>Idiopathic hemoptysis</td>
<td>10</td>
</tr>
<tr>
<td>Bronchiectasis</td>
<td>2</td>
</tr>
<tr>
<td>Lung carcinoma</td>
<td>1</td>
</tr>
<tr>
<td>Idiopathic coronary-to-bronchial artery</td>
<td>1</td>
</tr>
<tr>
<td>anastomosis</td>
<td></td>
</tr>
<tr>
<td>Congenital heart disease</td>
<td>1</td>
</tr>
<tr>
<td>Postembolic pulmonary hypertension</td>
<td>1</td>
</tr>
<tr>
<td>Pulmonary aspergilloma</td>
<td>1</td>
</tr>
<tr>
<td>Bacterial pneumonia</td>
<td>2</td>
</tr>
<tr>
<td>Sarcoidosis</td>
<td>1</td>
</tr>
</tbody>
</table>

**Results**

The outcomes of the 56 patients who underwent bronchial arteriography are presented in Figure 2.

**Immediate Control of Bleeding**

Of the 46 patients who underwent BAE, immediate arrest of hemoptysis was obtained in 43 patients (77% of initial 56 patients). BAE failed to control bleeding in three patients. Of these latter patients, two had a contraindication to surgery (nonsurgical lung carcinoma in one patient, impaired function in radiograph. Under local anesthesia, transfemoral bronchial arteriography was performed percutaneously using 5F or 4F catheter, if possible after cessation of vasopressin therapy. When no abnormal bronchial arteries could be identified, nonbronchial systemic arteries were opacified. In all cases, bronchial or nonbronchial arteries were found to be abnormal with arterial enlargement, regions of hypervascularity, or systemic-to-pulmonary shunting. The embolization materials used were absorbable particles of gelatin sponge (Spong; Houdé Laboratories; Paris, France) (n = 19) or nonabsorbable particles of microspheres (Embosphères; Guerbet Laboratories; Louvres, France) (n = 16), dura mater (n = 11), polyvinyl alcohol (Ivalon; Nycomed SA; Paris, France) (n = 6), and bucrylate (n = 3). Several types of embolization material were used in nine cases. Visualization of an anterior spinal branch or catheter instability were an absolute contraindication to the procedure.

Our approach in ill patients with hemoptysis consists of transcatheter embolization of the bronchial arteries most likely responsible for causing the bleeding rather than an exhaustive search for all bronchial or nonbronchial arteries.

Vascular interventional radiology is performed in our center by seven different radiologists. Every day, one of these seven physicians is on duty and may thus be called to perform BAE if necessary. Since some of these seven radiologists have moved to other institutions and have been replaced by others, 18 different angiographers have performed BAE during the study period. Concerning the expertise of the angiographers, they are asked to have a regular experience of vascular interventional radiology for at least 2 years before being accepted on the duty list. Despite these minimal criteria, the expertise and the skill of the different angiographers are obviously different.

**Analysis of Outcome**

Several aspects of outcome were analyzed retrospectively: immediate control of bleeding, recurrence of hemoptysis within the first month after BAE, recurrence of hemoptysis between 30 and 90 days after BAE, recurrence of bleeding beyond 3 months after BAE, and morbidity of the procedure. After the procedure, all patients were followed up at our center, with the exception of those who were operated on or who were unavailable for follow-up. The outcome of BAE was investigated from inpatient and outpatient medical records or, if needed, after direct contact with the patient or his physician, when the outpatient follow-up had ceased. For each patient, the end of follow-up was defined as July 1997 in patients for whom follow-up was available, the date of death, or the date after which the patient was unavailable for follow-up. The number of patients per follow-up interval is given in Figure 1.
the other) and died at day 1 from uncontrolled hemoptysis. An emergency pneumonectomy was performed in the third patient (Fallot tetralogy), but he eventually died 1 month later from recurrent hemoptysis from the opposite side.

Recurrence of Hemoptysis Within the First Month After BAE

Of the 43 patients with immediate control of bleeding after BAE, 2 patients died from causes other than hemoptysis, 2 patients underwent elective surgery, and 7 patients suffered relapse of bleeding. Thus, 32 of the initial 56 patients (57%) were managed successfully by BAE without recurrent bleeding for 30 days. In four of the seven patients who suffered relapse of bleeding, recurrent bleeding was observed within 10 days after the initial procedure leading to a second BAE. In all cases, the angiographer had to embolize additional bronchial or nonbronchial systemic collaterals to gain control of bleeding. Early recanalization of a bronchial artery initially embolized was never observed. Since a stable long-term result was obtained with the second procedure, the initial BAE was considered as a partial embolization and these four patients were included in the further follow-up. In the three other cases of recurrent bleeding, two nonsurgical patients (impaired lung function in one, metastatic lung carcinoma in the other) died within the first month after initial BAE despite a second BAE and one patient underwent elective surgery. By including the 4 patients with partial embolization, 36 patients were available for a longer follow-up at the end of the first month after initial BAE.

Recurrence of Hemoptysis Between 30 and 90 Days After BAE

During that period, six patients were unavailable for follow-up and one patient underwent elective surgery.
lobectomy. Twenty-eight of the 29 remaining patients had a stable result and 1 patient suffered relapse but did not need repeated BAE. Thus, 28 of initial 56 patients (50%) had successfully controlled conditions at 90 days and were available for further follow-up.

Recurrence of Bleeding Beyond 3 Months After BAE

The follow-up time ranged from 3 to 76 months (mean, 21 months; median, 13 months; interquartile range, 6 to 32.5 months).

Bleeding recurred in 3 patients but 25 of the initial 56 patients (45%) had no relapse during the period of follow-up. There was no recurrence of hemoptysis after 24 months postembolization.

Outcome by Angiographer

In this series, the number of BAEs performed by each angiographer ranges from 1 to 6. One angiographer performed six BAEs but in the other cases, the number of BAEs performed by each angiographer was always four or less. Thus, the sparse experience of each angiographer does not enable us to detect if there was operator-dependent variations in outcome.

Outcome by Type of Material Used

In the six cases in which BAE failed to control bleeding during the first month, the embolization materials were as follows: gelatin sponge (n = 2), microspheres (n = 2), polyvinyl alcohol (n = 1), and gelatin sponge + bucrylate (n = 1).

In the four cases of bleeding relapse occurring beyond the first month after BAE, embolization materials were dura mater (n = 1), polyvinyl alcohol + gelatin sponge (n = 1), dura mater + gelatin sponge (n = 1), and polyvinyl alcohol (n = 1).

Cumulative Hemoptysis Control Rate

A Kaplan-Meier curve (Fig 3) describing the cumulative probability of survival without recurrence of bleeding in the 46 patients who underwent BAE shows that the overall cumulative hemoptysis control rate was 87% at 1 month, 84% at 3 months, 81% at 4 months, 77% at 1 year, and 69% at 2 years (the four patients with secondary success have been counted as success of BAE and not as relapse of bleeding).

Complications

The complications of 50 BAE procedures in the 46 patients consisted of subintimal dissection of the aorta leading to mediastinal hematoma with a favorable spontaneous outcome (n = 2 patients), transient thoracic pain (n = 1 patient), transient leg pain with normal arteriography (n = 1 patient), and spinal cord complications (n = 3 patients). The latter complications were Brown-Séquard syndrome that regressed after 4 months without sequelae (n = 1 patient), paraparesis with spontaneous regression after 2 weeks (n = 1 patient), and complete paraplegia without regression (n = 1 patient).

Figure 3. Cumulative hemoptysis control rate for the 46 patients who underwent BAE, calculated by the Kaplan-Meier method. Control rate was 87% at 1 month, 84% at 3 months, 81% at 4 months, 77% at 1 year, and 69% at 2 years. There was no recurrence of hemoptysis after 24 months postembolization.
Discussion

Life-threatening hemoptysis was defined in our series as expectoration of at least 200 mL of blood per hour in a patient with normal or nearly normal lung function, production of at least 50 mL of blood per hour in a patient with a chronic respiratory failure, or more than two episodes of moderate hemoptysis (at least 30 mL) within a 24-h period despite the use of IV vasopressin. We have not taken into account the amount of blood expectorated during a 24-h period since the decision to perform BAE is generally not made on this basis. Although other definitions of life-threatening hemoptysis with various amounts of blood produced within 24 h have been proposed in the literature, we have used a more functional definition: hemoptysis that poses a threat to life.

Our data indicate that BAE is able to achieve an immediate control of hemoptysis in most cases, confirming that systemic circulation is the primary source of bleeding in hemoptysis. This result is in accordance with previous reports in which BAE resulted in an immediate arrest of bleeding in 75 to 90% of the patients. Within the first month after BAE, recurrence of bleeding was not unusual since relapse was observed in 7 of 46 patients. We believed that we had to individualize those patients with a relapse within 2 weeks after the initial procedure and in whom the second procedure led to a stable result for at least several weeks. In these cases, rebleeding was not due to vessel reperfusion or development of a collateral circulation but to an incomplete initial procedure. The possibility of an incomplete initial BAE is inherent to the protocol of minimal intervention in use in our center, consisting of a nonexhaustive embolization of all arteries supplying the bleeding site.

In terms of initial management of life-threatening hemoptysis, surgery should, for some authors, be indicated on an emergency basis if the bleeding point is localized and if pulmonary function tests permit pulmonary resection. The main advantage of surgery is that it permits a definitive treatment of hemoptysis because it removes the source of bleeding. Emergency surgery, however, is associated with a high mortality rate. In the light of our results, we continue to favor BAE as the initial intervention since it stops the bleeding in most cases. Emergency surgery should be reserved for those patients who continue to suffer life-threatening hemoptysis despite BAE. When the bleeding has stopped, surgery should be considered on an elective basis for the definitive treatment of anatomically localized lesions because severe hemoptysis may recur in the short term and lead to death.

Concerning medium-term and long-term results of BAE, it is sometimes considered a palliative technique with a relapse of bleeding occurring in a significant number of patients if a definitive treatment is not performed. Some studies have already addressed the issue of long-term results after BAE and have demonstrated that rebleeding, attributed to reperfusion of the embolized artery(ies) or to development of a collateral circulation may indeed occur but only in a minority of patients. Depending on the length of follow-up, recurrence rate varied in these studies between 0% and 28% of the patients available for follow-up. In our study, the rate of recurrence was low, between 1 and 3 months after BAE, although several patients have been unavaiable for follow-up. Beyond 3 months after the procedure, hemoptysis recurred in 3 of the 28 patients available for follow-up, confirming that in patients who are not surgical candidates, BAE may most often control recurrence of hemoptysis, even for a long period of time.

Recurrence rate after BAE is probably influenced by the etiology of hemoptysis. In patients with aspergilloma, the recurrence rate has been found to be higher than in patients with active tuberculosis that can be treated by effective drugs. Thus, the high prevalence of tuberculosis in our series may have played a role in the relatively low long-term bleeding relapse.

Technical failure of the attempted embolization was observed in 10 of the 56 patients who underwent bronchial arteriography. The reasons for this technical failure were inability to cannulate the vessel, instability of the catheter tip, or visualization of the anterior spinal artery. While the rate of technical failure was 0 to 13% in other reports, it was higher in our study. The underlying reasons include the frequent use of IV vasopressin, the elevated age of our patients, the differing skills of the 18 radiologists, and the fact that visualization of the anterior spinal artery was an absolute contraindication to BAE.

Complications of BAE have not been rare in our series. Spinal cord injury related to invisible anastomotic connections between the bronchial circulation and the anterior spinal artery, subintimal dissection of the aorta, and transient thoracic pain have already been observed in several studies as well as other minor or major complications. The potential risks of the procedure imply that BAE should be reserved for patients with life-threatening hemoptysis and should be avoided in patients with minor hemoptysis or when the bleeding has ceased with medical treatment. Although visualization of the anterior spinal artery was an absolute contraindication to embolization in our center, our frequency of
spinal cord injury was high as compared with several large series of BAE \(^7,^8,^11\) in which no neurologic complications were observed. However, our rate of neurologic complications is in accordance with other reports \(^23,^24\) suggesting that in some cases, vital cord supply may not be visualized. Our feeling is that the true frequency of spinal cord injury after BAE is probably underestimated by the medical literature, the latter reporting mainly the experience of centers overspecialized in BAE. Our rate of neurologic complications is probably a good reflection of what can be observed in standard centers performing BAE, like ours. To lower the incidence of spinal cord injury, monitoring with somatosensory-evoked potentials has been proposed by some authors \(^15,^24\) as well as the use of superselective BAE with a coaxial microcatheter system. \(^22\) These techniques could represent an interesting means to prevent spinal cord ischemia but will probably never eliminate the risk of complications.

In summary, our study confirms that BAE is an effective technique in the emergency treatment of life-threatening hemoptysis but shows that complications are not rare. In view of our results, we continue to favor the simplest and the quickest procedure, most likely to control hemoptysis at first embolization, rather than perform an exhaustive search for collateral circulation. During the first month after BAE, recurrences of bleeding are frequent and may be lethal. Thus, it seems advisable to perform an elective surgical treatment before discharge from the hospital. However, for patients who have a contraindication to surgery, BAE alone is able to achieve long-term control of bleeding in most of them.

**REFERENCES**


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